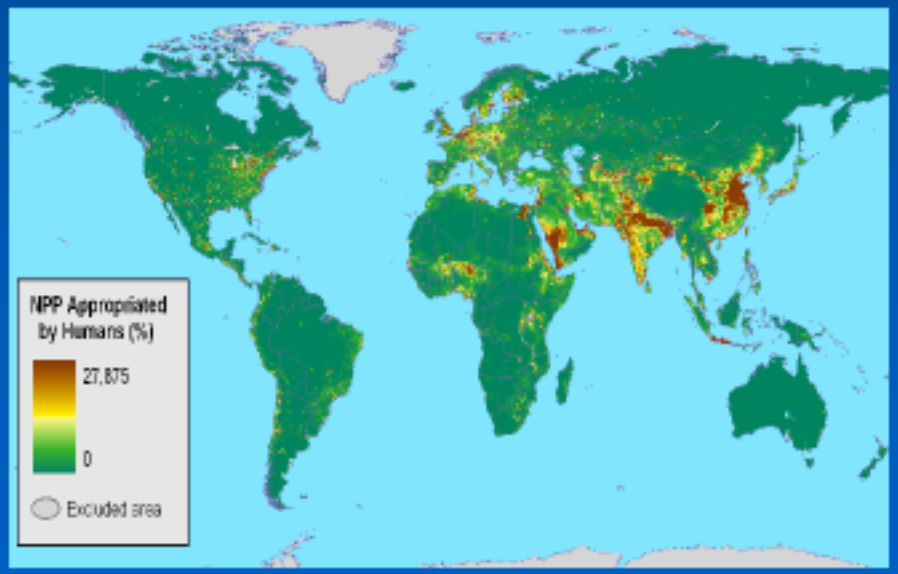
Consequences of Urbanization on NPP-Carbon in North America
&
Human Appropriation of NPP Carbon

CARBON-0000-0009

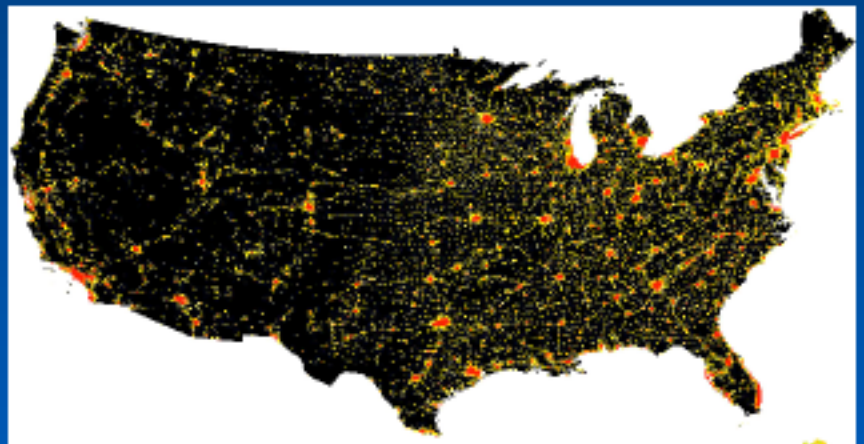
M. L. Imhoff, L. Bounoua, Taylor Ricketts, and Colby Loucks
NASA's GSFC, UMD ESSIC, WWF

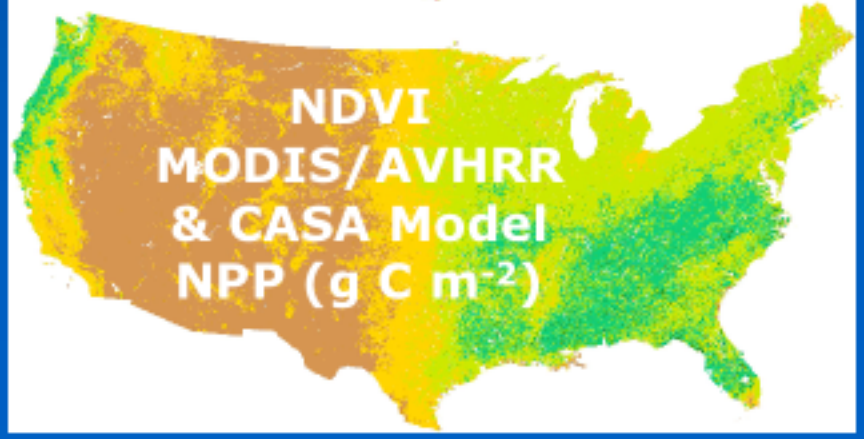


HQ Site Visit to GSFC, March 16, 2004.

Consequences of Urbanization on NPP-Carbon in North America

Urbanization Data DMSP-OLS





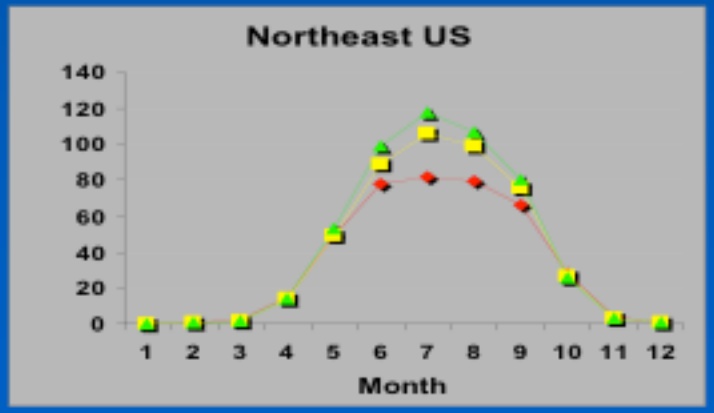
REDUCED CARBON INPUT

Annual NPP reduced by 1.6% (40 million tons) offsetting gain made by agriculture.

Reduction in food production alone equivalent to needs of 16 million persons/year.

URBAN HEATING

Satellite evidence of urban heating. Extends length of growing season locally in cold climates.



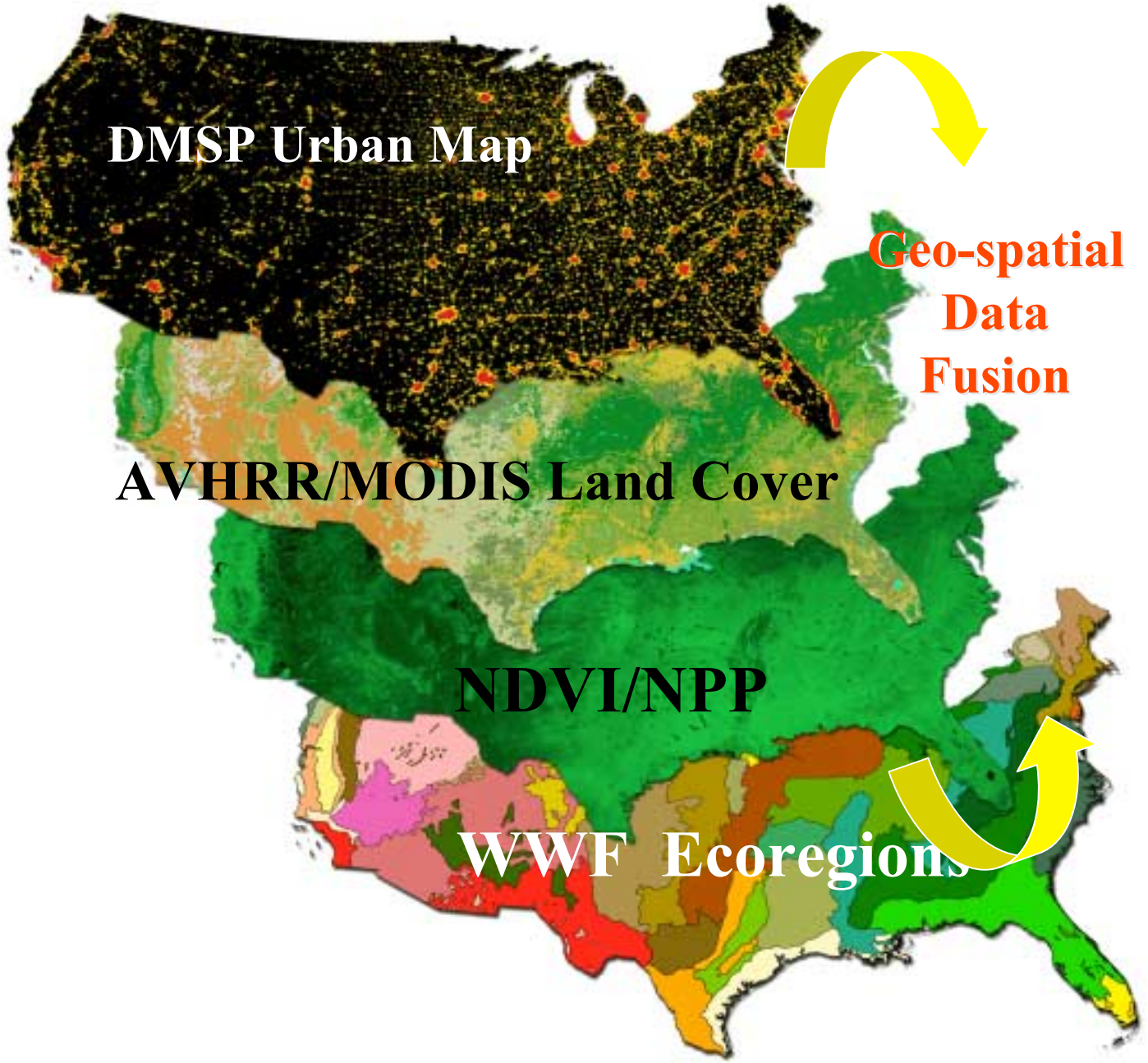
M. L. Imhoff, L. Bounoua, T. Ricketts, and C. Loucks, GSFC/UMD/WWF

Questions

- What is the overall impact of urbanization on NPP in North America?
  - Has the NPP-carbon sink been reduced by urbanization? If so how much?
  - What are the consequences in terms of biological energy input?
- How does urbanization interact with climate locally?
  - Is there a recognizable effect in the NDVI signal at 1km spatial resolution?
  - What are the seasonal dynamics?
  - How does local climate affect the impact of urbanization on NPP balance (positive or negative)?

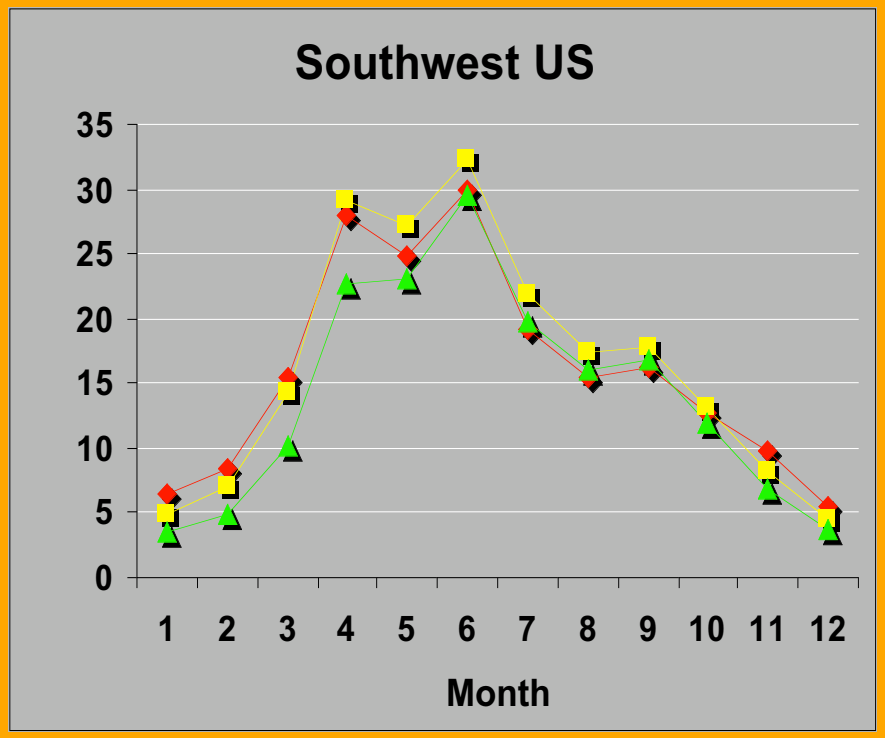
METHOD

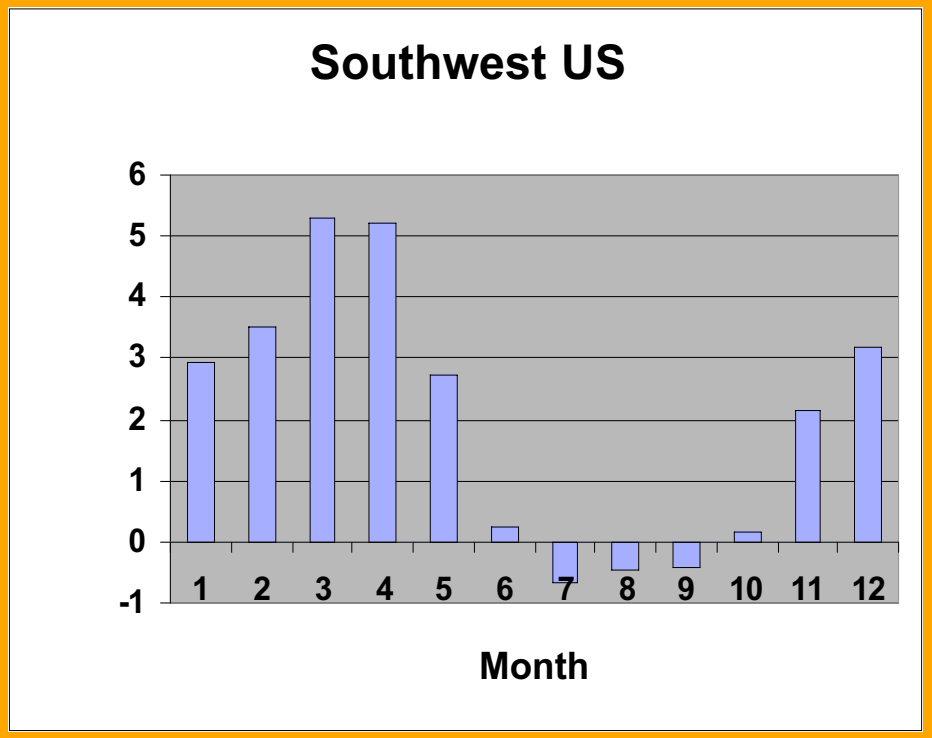
- Compare photosynthetic productivity (NPP) inside and outside urbanized areas.
  - Define urban areas - DMSP
  - Define NPP of landscape
    - Carnegie-Stanford-Ames carbon model (CASA)
    - AVHRR composite data Maximum Monthly NDVI
- Overlay DMSP "urban map" on NPP fields.
  - How does urbanization interact with climate locally?
- Estimate the PRE-urban annual NPP.
- Compare with Current NPP profile
  - Pre-urban / Post-urban NPP difference.


DMSP Urban Map
Geo-spatial
Data
Fusion
AVHRR/MODIS Land Cover
NDVI/NPP
WWF Ecoregions

Seasonal Dynamics of NPP for Cities in the Southwestern United States

Resource augmentation (irrigation, fertilization) and planting of exotic species increases production in and around urban areas.

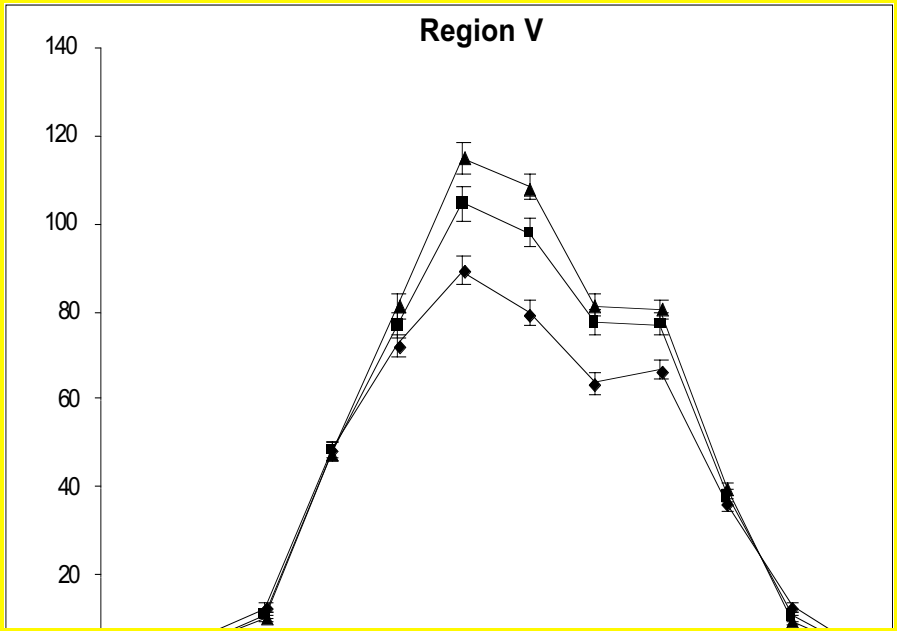


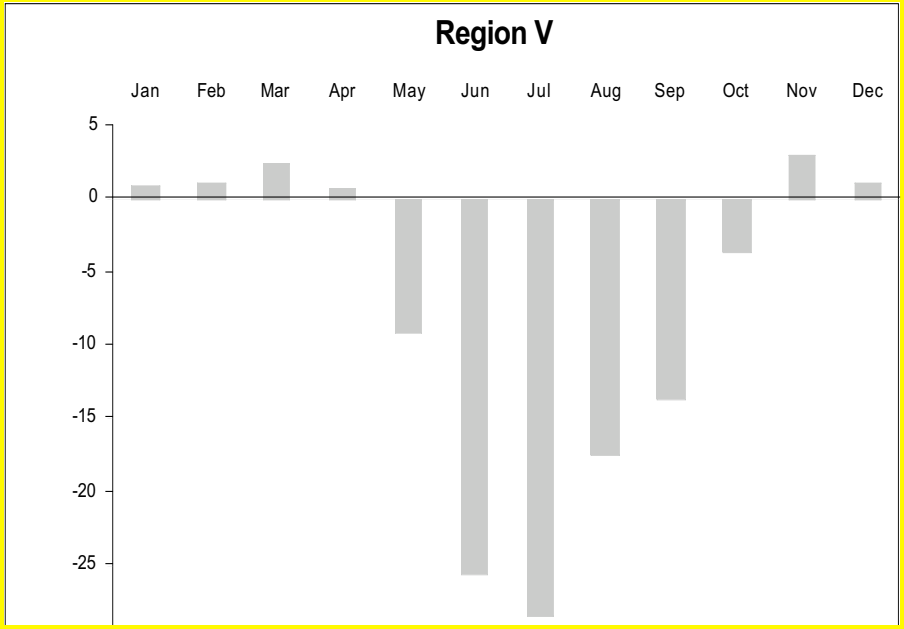


Productivity increased by more than 24 g/m^2 annually.

Seasonal Dynamics of NPP for Cities in the Mid Atlantic Region

Urban heating increases NPP in urban areas by 9 g/m^2 from November through April



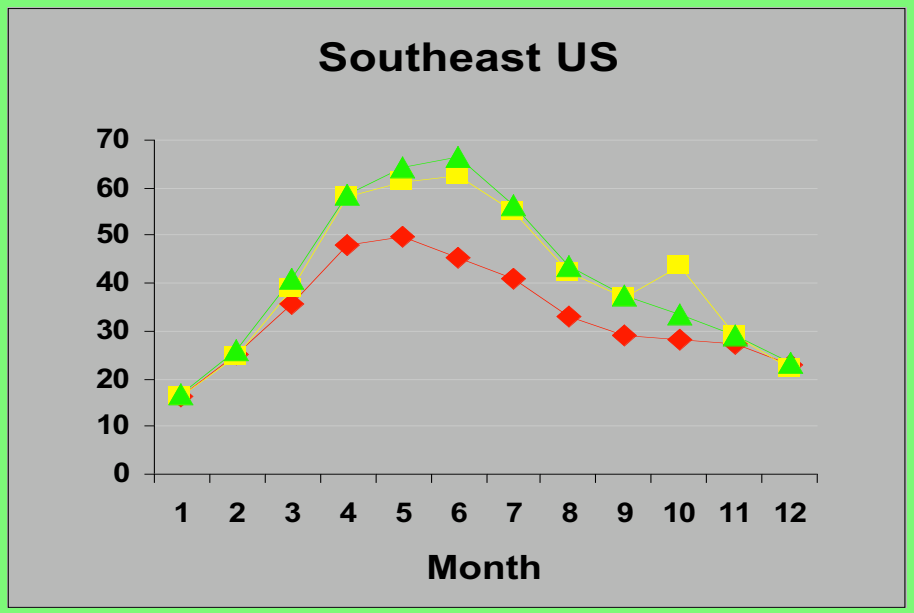


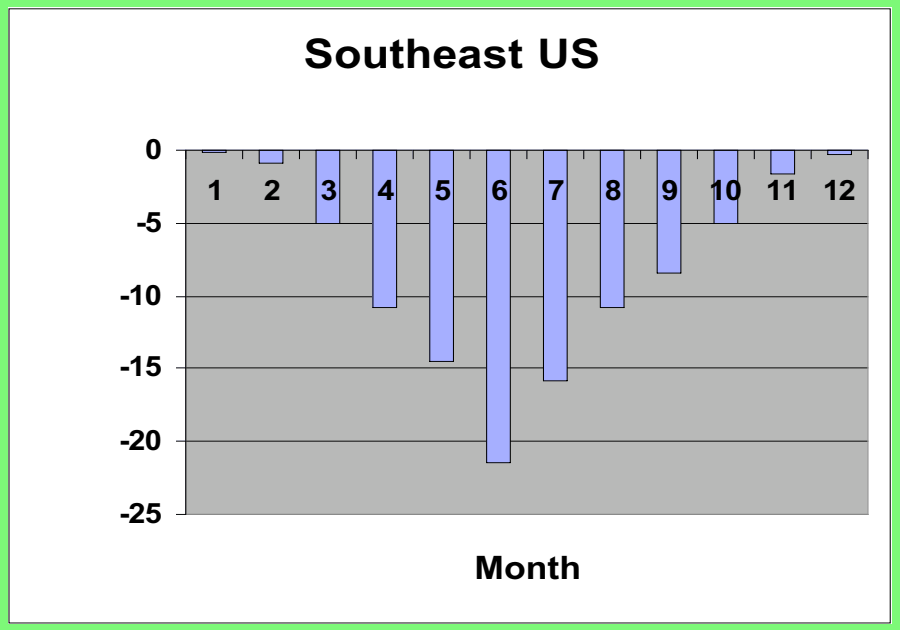
Fractional area reduced by replacement and heat stress

Productivity reduced by more than 89 g/m^2 annually.

Seasonal Dynamics of NPP for Cities in the **Southeastern** United States

Urban heating conveys no advantage in warm climates and significantly decreases fractional area year around.





Fractional area decreased by replacement and heat stress

Productivity reduced by more than 95 g/m^2 annually.

NPP Difference Map

Pre-urban NPP minus Post-Urban NPP

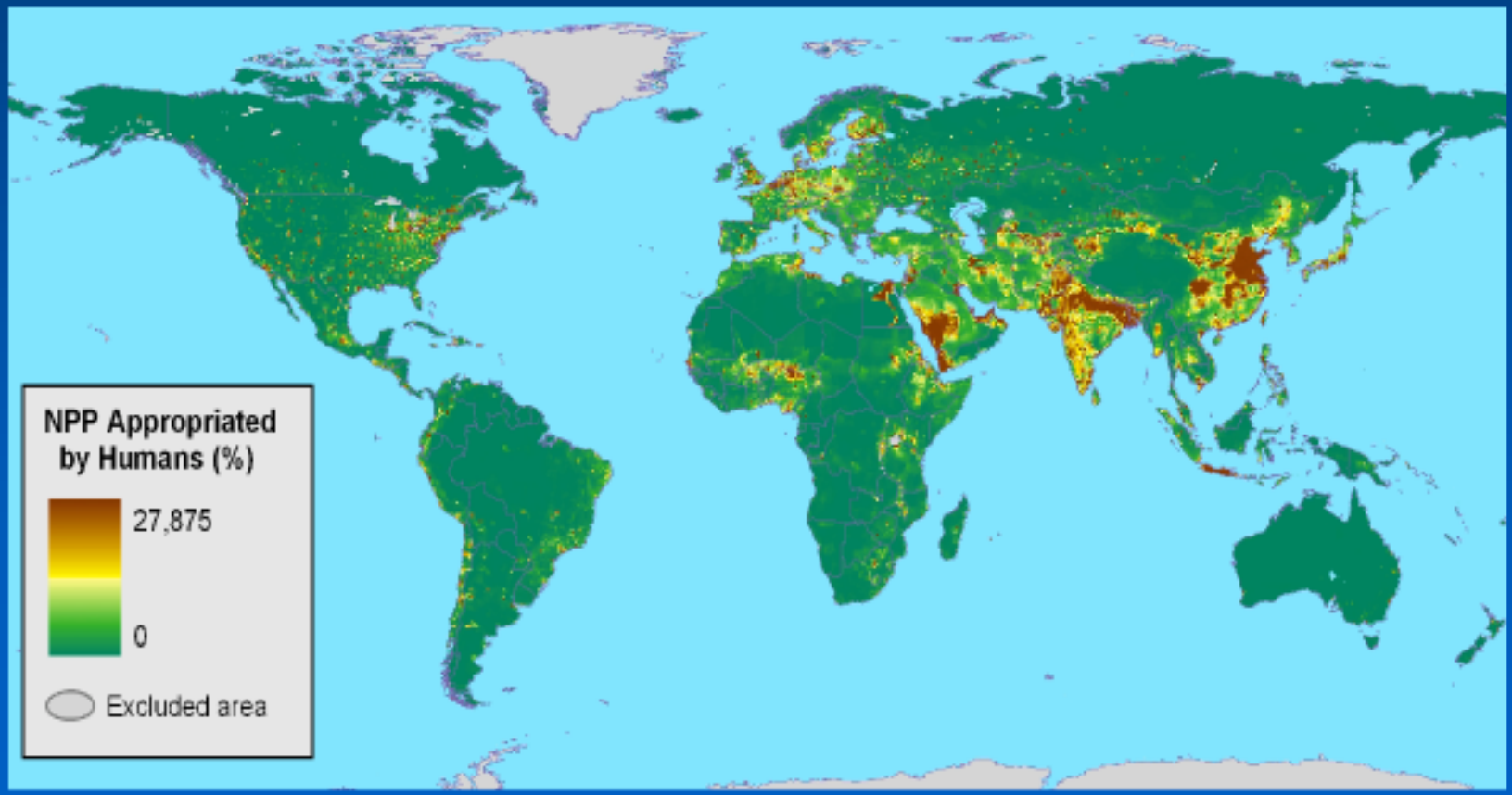
Significant Results

- Urbanization occupies 3% of land surface, agriculture 29%
    - Urbanization decreased the terrestrial carbon sink in the US roughly equivalent to increase created by agriculture.
- Urban heating influences local phenology
  - Extends length of growing season locally in cold climates
    - Winter gain in NPP is negated by reduced fraction area in vegetation and heat stress in peak season
    - Seasonal offset diminishes approaching tropics
- Reduction of NPP may have biological significance
  - Loss to food web equal to calories used by 448 million people annually.
  - Annual reduction from former agricultural lands equates to food Calories sufficient for 16.5 million persons annually (about 6% of US population)

Human Appropriation of NPP Carbon:

CARBON-0000-0009

M. L. Imhoff, L. Bounoua, Taylor Ricketts, and Colby Loucks
NASA's GSFC, UMD ESSIC, WWF



2004 LCLUC/CARBON Meeting, University of Maryland, January 22-24.

NPP Carbon

"Common Currency" for
Climate Change, Ecological, & Economic Assessment

- A compelling measure of humanity's cumulative impact is the fraction of the planet's net primary production (NPP) humans appropriate for their own use (Vitousek et al. 1986).
  - **NPP is the primary energy source for the world's ecosystems:**
    - **Ecosystem services** (Daily et al. 1997),
    - **Biodiversity** (Pimm and Gittleman 1992, Sala et al. 2000,Haberl et al. 1997)
    - **Energy flows within food webs** (Field 2001, Cardoc et al. 2002).
  - **An important mechanism in the cycling of carbon between the atmosphere and biosphere** (Schimel et al. 2000).
- Humans appear to exert a remarkable demand on planetary NPP for a species that represents roughly 0.5% of Earth's total heterotroph biomass.
  - **Past studies estimate that humans appropriate between 3% and 55% of Earth's NPP** (Vitousek et al. 1986, Rojstaczer et al. 2001)

Defining Human Appropriation

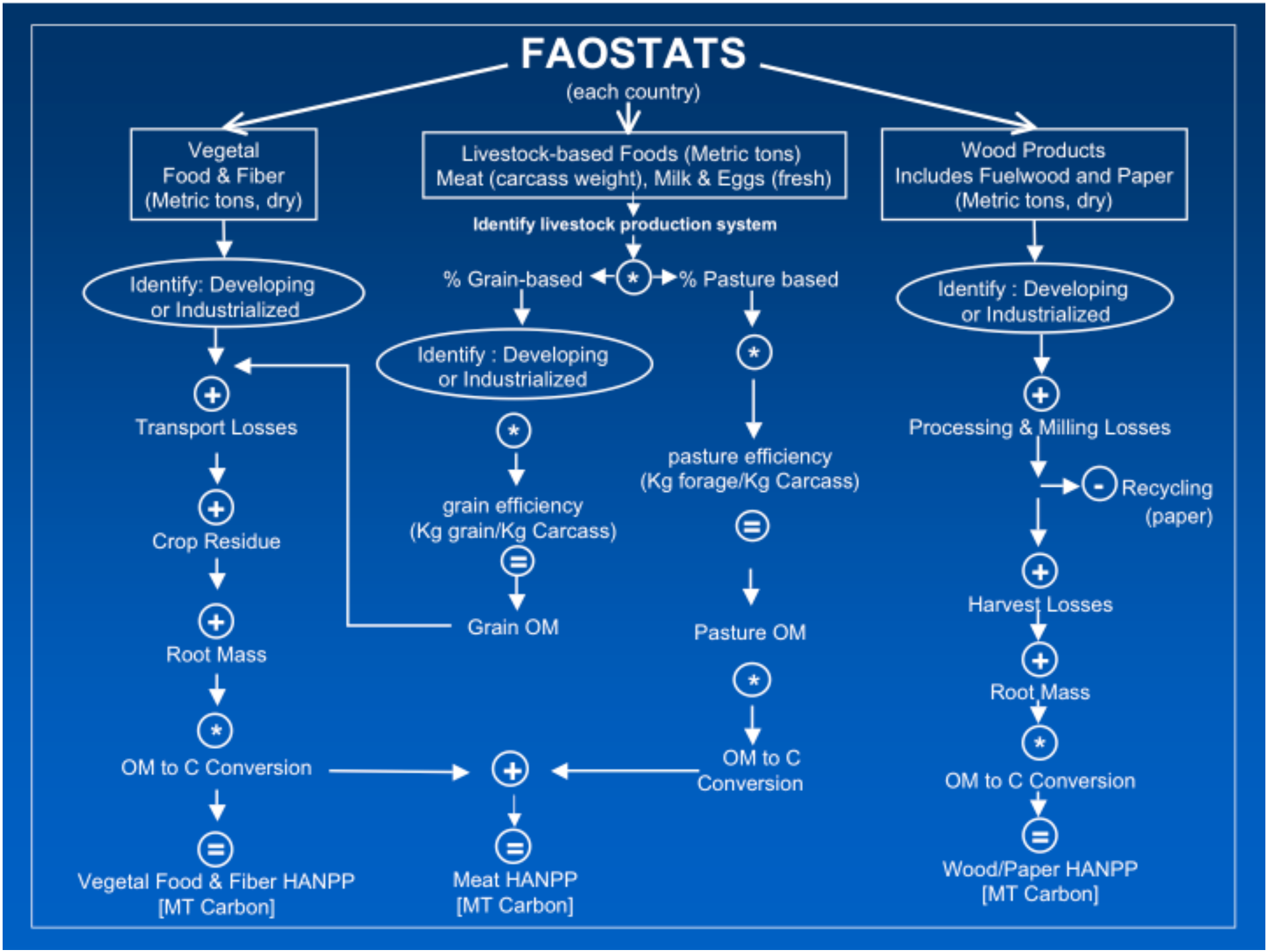
- Past studies used biome-averaging to estimate NPP appropriation.
  - **- did not allow for spatial representation**
  - **- contained considerable uncertainties for not including spatially heterogeneous processes**

- We developed a new approach:
  - **Constrains the model to observations INPUT:OUTPUT (UNFAO, Satellite)**
  - **Scalable to change in spatial resolution and input data**
  - **Flexible for assessment of scenario-studies.**
  - **Can be compared to satellite-supported global NPP and LCLUC products.**

NPP Carbon "Demand" Model

Goal: Estimate the amount of NPP required "in the field" to create food and fiber products.

- **Consumption-based.**
  - ***United Nations Food and Agricultural Organization (UNFAO-STATS) statistics used as input.***
- **Country level & Product Specific**
  - *Domestic Supply = Production + Imports – Exports*
  - **Vegetal Foods, Livestock-based Products, Wood, Paper, and Fiber.**
- **Landscape relevant.**
  - **Bio-agronomic modules back-calculate the NPP required to produce the consumed products.**
    - **Harvest, processing, and livestock parameters (literature).**
    - **Separate parameterization for Developing vs Industrialized countries.**
- **Multi-dimensional indexing.**
  - **Demographic and spatial via *per capita* NPP consumption.**


FAOSTATS
(each country)
Vegetal
Food & Fiber
(Metric tons, dry)
Livestock-based Foods (Metric tons)
Meat (carcass weight), Milk & Eggs (fresh)
Wood Products
Includes Fuelwood and Paper
(Metric tons, dry)
Identify livestock production system
Identify: Developing
or Industrialized
% Grain-based
% Pasture based
Identify : Developing
or Industrialized
Identify : Developing
or Industrialized
Transport Losses
grain efficiency
(Kg grain/Kg Carcass)
pasture efficiency
(Kg forage/Kg Carcass)
Processing & Milling Losses
Recycling
(paper)
Crop Residue
Grain OM
Pasture OM
Harvest Losses
Root Mass
Root Mass
OM to C Conversion
OM to C
Conversion
OM to C Conversion
Vegetal Food & Fiber HANPP
[MT Carbon]
Meat HANPP
[MT Carbon]
Wood/Paper HANPP
[MT Carbon]